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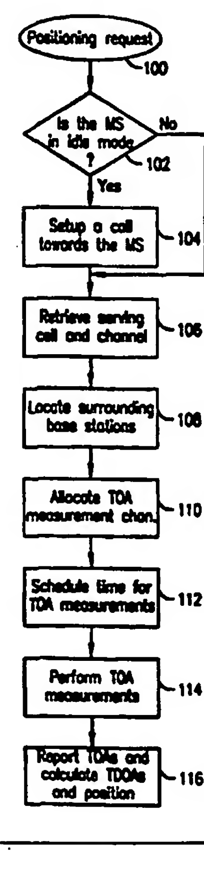
(54) Title: POSITIONING SYSTEM AND METHOD FOR CELLULAR MOBILE RADIO

(57) Abstract

A method and system are disclosed for determining the position of mobile stations based on Time Difference of Arrival measurements, which can be applied to digital mobile radiotelephone networks such as, for example, in the GSM. In a preferred embodiment, the network (12) retrieves the identity of the serving cell (BS1) and serving channel allocated for the mobile station (14) whose position is to be determined, locates a plurality of base stations (BS 2-4) surrounding the serving cell (BS1), allocates a measurement channel for each of the surrounding base stations so located, and schedules a measurement time for the located surrounding base stations. Each base station (BS 2-4) then performs a Time of Arrival measurement at the scheduled measurement time, and reports the measurement information to the network (12). The network (12) uses the Time of Arrival measurement information to calculate Time Difference of Arrival information, and thus derives the mobile station's (14) position.



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POSITIONING SYSTEM AND METHOD FOR CELLULAR MOBILE RADIO

CROSS-REFERENCES TO RELATED APPLICATIONS

This Application for Patent claims the benefit of priority from, and hereby incorporates by reference the entire disclosure of, co-pending U.S. Provisional Application for Patent Serial No. 60/067,113, filed December 1, 1997.

This Application is also related by subject matter to commonly-assigned U.S. Patent Application Serial No. 08/894,466, filed August 18, 1997, which is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates generally to the mobile telecommunications field and, in particular, to a method and system for determining the position of mobile stations (MSs) in a cellular Time Division Multiple Access (TDMA) system.

Description of Related Art

There is a wide range of applications where the global position of an MS in a cellular system is of great interest. For example, it is important to be able to determine the position of MSs involved in emergency calls (police and fire vehicles) or for fleet management purposes (e.g., taxi companies). As such, a number of different solutions have been proposed for determining the location of MSs. There are terminal-based solutions such as MSs with built-in Global Positioning System (GPS) receivers, as well as network-based solutions such as the one disclosed in Swedish Patent Application No. 9303561-3 to R. Bodin.

In this Swedish Application, a "positioning handover" method is used to determine the position of an MS. However, notwithstanding the advantages of this method, there are still some problems that exist, such as, for example, a risk of losing calls, and the relatively long period of time it takes to perform the positioning procedure. However, such problems are solved by the method

disclosed in commonly-assigned U.S. Patent Application Serial No. 08/977,470 filed November 24, 1997, whereby only one positioning handover has to be made.

In both of the above-described cases, access delays are measured that represent the absolute distance to the MS. The MS's position is then calculated by triangulation. In other words, the MS's position is located at or near the point where a plurality of plotted circular arcs cross over one another.

An alternative positioning method is to base the position determinations on Time Difference of Arrival (TDOA) calculations, which are further based on Time of Arrival (TOA) measurements. In this case, an MS's position is located at or near the point where a plurality of hyperbolic arcs cross over one another. This approach advantageously provides more accurate positioning information than non-TDOA approaches, because the measurements made are dependent only on the different uplink delays. Another advantage of this approach is that the MS positioning can be performed without disturbing any ongoing communications.

A TDOA positioning method is used by Trueposition®. This approach uses separate positioning receivers (Signal Collection System or SCS) to sample the uplink waveform and transfer all data to a common TDOA Location Processor (TLP), which correlates the information with known transmitted sequences.

The above-cited, commonly-assigned U.S. Patent Application Serial No. 08/894,466 (hereinafter, the "'466 Application") discloses a TDOA positioning solution which is integrated into the mobile telephone system (e.g., for the Digital-Advanced Mobile Phone System or D-AMPS). For this approach, a correlation with known bit sequences is performed in special purpose receivers that are integrated into the base station (BS).

A shortcoming of the prior MS TDOA positioning approaches is that they describe only generally how a TDOA positioning method can be used with certain digital TDMA cellular systems. In particular, the prior art does not disclose how MS TDOA positioning techniques can be applied to the Global System for Mobile Communications (GSM). Furthermore, the prior MS TDOA approaches do not address certain problems, such as the risk associated with performing handovers during the position determination process, or positioning while listening to channels using logical channel multiplexing and discontinuous transmissions.

However, as described in detail below, the present invention successfully resolves the above-described problems.

SUMMARY OF THE INVENTION

In accordance with the present invention, a method and system are provided for determining the position of MSs based on TDOA measurements, which can be applied to digital mobile radiotelephone networks such as, for example, in the GSM. In a preferred embodiment, the network retrieves the identity of the serving cell and serving channel allocated for the MS whose position is to be determined, locates a plurality of BSs surrounding the serving cell, allocates a measurement channel for each of the surrounding BSs so located, and schedules a measurement time for the located surrounding BSs. Each BS then performs a TOA measurement at the scheduled measurement time, and reports the measurement information to the network. The network uses the TOA measurement information to calculate TDOA information, and thus derives the MS's position.

An important technical advantage of the present invention is that a TDOA MS positioning method is provided for digital TDMA cellular systems, such as, for example, the GSM.

Another important technical advantage of the present invention is that a method for determining the position of an MS is provided wherein the risk of losing connections while performing MS positioning handovers is significantly reduced.

Yet another important technical advantage of the present invention is that a method for determining the position of an MS is provided wherein the risk associated with determining an MS's position while listening to channels using logical channel multiplexing or discontinuous transmissions is significantly reduced.

Still another important technical advantage of the present invention is that a method is provided for determining the position of MSs wherein the positioning accuracy is significantly higher than prior methods.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a diagram of a mobile radiotelephone system overview that can be used to illustrate a number of methods for determining the position of MSs, in accordance with preferred embodiments of the present invention;

FIGURE 2 is a flow diagram that can be used to implement an exemplary embodiment of the present invention for an ongoing connection in a synchronous network similar to that shown in FIGURE 1;

FIGURE 3 is a diagram that helps to better illustrate the exemplary TOA measurement method described with respect to FIGURE 2;

FIGUREs 4A and 4B are related diagrams that illustrate how a TN can be calculated for allocation in a detector's BS;

FIGURE 5 is an exemplary frame timing diagram that illustrates how to provide a guaranteed measurement window, in accordance with the second embodiment of the present invention;

FIGURE 6 is a flow diagram that illustrates a method for determining the position of an MS using controlled transmission of access bursts in a synchronous network, in accordance with the third exemplary embodiment of the present invention;

FIGURE 7 is a diagram that illustrates how an existing handover command method can be implemented for the third exemplary embodiment of the present invention;

FIGURE 8 illustrates a situation when an access burst transmitted by a MS is received by a serving BS and detectors; and

FIGURE 9 is a diagram that illustrates how TOA measurements can be made, in accordance with the fourth exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

The preferred embodiment of the present invention and its advantages are best

understood by referring to FIGUREs 1-9 of the drawings, like numerals being used for like and corresponding parts of the various drawings.

Essentially, in accordance with the present invention, a method and system are provided for determining the position of MSs based on TDOA measurements, which can be applied to digital mobile radiotelephone networks such as, for example, in the GSM. In a preferred embodiment, the network retrieves the identity of the serving cell and serving channel allocated for the MS whose position is to be determined, locates a plurality of BSs surrounding the serving cell, allocates a measurement channel for each of the surrounding BSs so located, and schedules a measurement time for the located surrounding BSs. Each BS then performs a TOA measurement at the scheduled measurement time, and reports the measurement information to the network. The network uses the TOA measurement information to calculate TDOA information, and thus derives the MS's position.

Specifically, FIGURE 1 is a diagram of a mobile radiotelephone system overview that can be used to illustrate a number of methods for determining the position of MSs, in accordance with preferred embodiments of the present invention. At this point, it is useful to discuss some basic assumptions that may be made with regard to the system shown in FIGURE 1. For example, all TOA and/or TDOA measurements can be made at receivers located at the different BSs in the network. As a synchronous network, all of these receivers are highly accurately time-synchronized to a single global time reference. However, the actual synchronization accuracy required should depend on the specific network operating scenarios and applications involved. An exemplary method that can be used to attain highly accurate global time synchronization is to locate a GPS receiver (highly accurate time base) as a time reference at each BS's site.

As a basis for obtaining accurate calculations of the MS' positions, the geographic location of each BS should be known. More precisely, the exact locations of the phase centers of the antennae that feed the receivers' detectors should be known, as well as the exact signal delays from the antennae to the respective receiver detectors. Notably, if these signal delays are known, then their effects can be adequately compensated for.

As such, an exemplary method that can be used for determining the position

of an MS in the system shown in FIGURE 1 is described in the '466 Application. This exemplary method can be summarized as follows. First, a positioning request for an MS is issued (by a user or network operator) at the user interface (UI) of a mobile positioning service node 10. The request is then forwarded from the service node to a mobile services switching center (MSC) 12 in the cellular network. In a GSM network, the MSC can be combined with a base station controller (MSC/BSC). At least three BSs (e.g., BS1, BS2, BS3) with antennae at different locations detect a signal (waveform) transmitted from the MS 14 whose position is to be determined. Each such BS then measures the TOA of the detected signal at the BS's respective site. The waveform used by the MS 14 may be ordered by the network (e.g., when a new connection is to be established, or a handover has been ordered), or it can be in the form of signals that are normally transmitted from the MS (e.g., speech frames). Notably, in order to be able to accurately measure the TOA of a transmitted signal, the existence of the signal should be known in advance by the BS involved. Alternatively, the incoming signal waveform can be sampled and conveyed to a central location for further processing. This is similar to an approach used by TruePosition®.

For the next step, information related to the TOA measurements is conveyed from the BSs to the mobile positioning service node 10 (via the MSC/BSC 12). A triangulation procedure to determine the MS's position is performed in the mobile positioning service node 10 based on the TOA information received from at least three BSs, and the known coordinate information for those BSs. The MS's position is then conveyed to the user or operator via the UI of the service node 10.

As such, the present invention provides a number of alternative methods (embodiments) for determining the position of an MS, which improve significantly on the above-described method. FIGURE 2 is a flow diagram that can be used to implement an exemplary embodiment of the present invention in a network similar to that shown in FIGURE 1. Essentially, the method illustrated by FIGURE 2 can be used to determine an MS's position by listening to an ongoing connection in a synchronous network. The network can thus be assumed to be synchronized for this embodiment (i.e., the timing of the air interface is common to all cells in the network). However, the cells may be offset in Frame Number (FN) counting. After receiving the positioning request, the serving cell and actual serving channel in use by that MS (e.g.,

14) are noted by the network (e.g., service node 10). The network then allocates detectors in a number of the BSs surrounding the serving cell. For this embodiment, from one to several Normal Bursts can be transmitted from the MS and used for the TOA measurements.

Referring to FIGUREs 1 and 2, at step 100, the positioning request for a MS (e.g., 14) is made. At step 102, if the network (MSC/BSC 12) determines that the MS 14 is in the idle mode, then at step 104, the network initiates a call setup procedure for that MS. Otherwise, at step 106, the network continues the positioning procedure. Using identity information about the MS (e.g., IMSI in the GSM), the network retrieves the MS's occasional cell location (e.g., stored in the MSC/BSC in the GSM). The network also retrieves a description of the channel allocated to the MS 14. Although it is possible that the MS can leave the channel before the end of the measurement period, an option can be exercised to inhibit a channel change or release during this period. In other words, handovers from the channel should be avoided where possible, and releases, for example, could be delayed. In any event, if the MS has to leave the channel for some reason, then the positioning procedure should be interrupted, and the cause of the interruption should be determined before proceeding further.

In the GSM, the Channel Description contains the following parameters: Channel Type and TDMA Offset information indicate the type of channel involved (e.g., TCH/F, SDCCH/8) and subchannel number; TN is the Timeslot Number in the air interface (0-7); H is the Hopping Channel, where "0" represents a Single RF Channel, and "1" represents an RF Hopping Channel; H=0 represents an Absolute Radio Frequency Channel Number (ARFCN); H=1 represents a Mobile Allocation Index Offset (MAIO) and Hopping Sequence Number (HSN), which are parameters that describe the hopping sequence (in this case, the Mobile Allocation (MA) with all frequencies in the hopping set should also be retrieved); and Training Sequence Code (TSC) (0-7), which identifies any of 8 possible fixed Training Sequences (26 bits) used in all Normal Bursts transmitted over the air interface. The Training Sequence is then used in the detector for correlating with the received information (i.e., for determining the position of the burst in time).

In general, any information that describes the incoming bursts can be

forwarded to the detector. A longer Training Sequence can improve the receiver's sensitivity. In other words, in general, the MS is expected to transmit a code, x, at time T. The code, x, can be loaded into the detectors prior to time T. The detectors can then capture the transmitted code subsequent to time T, and measure the delay between time T and the instant when the code is captured.

As mentioned earlier for this method, the radio network should be synchronized. In other words, the air interface timing for all cells is synchronized. However, the synchronized cells are preferably offset in time (FN counting), because in the GSM, the MSs measure signal strength and decode information about neighboring cells. Consequently, the measurements would take much longer to perform if all of the cells had the same FN time. Each cell is thus offset in time by use of the parameter, FN Offset, which is retrieved from the serving cell and forwarded to the respective detector.

At step 108, the network (e.g., accessing a lookup table) determines what BSs (detectors) surround the serving cell. Preferably, these surrounding BSs are located at sites other than that of the serving BS. It is advantageous if all BSs likely to be able to detect the MS's transmitted bursts within their respective measurement windows can be identified. One approach is to use the list of neighbor cells produced by conventional methods as candidates for handover. A neighbor cell list can be produced as a result of MS measurements. As such, the neighbor cells on the list at the same sites as the serving cells are canceled, and out of the remaining cells, at least one cell (e.g., the "best" one) for each BS site is selected. However, a shortcoming of this approach is that the neighbor cell list might exclude some BSs that could be used for performing TOA measurements. For example, the sensitivity of those BS's detectors could be better than the sensitivity of the MS's itself.

Another approach to identify such BSs is for the network to lookup in a database, which stores pertinent information about the positions of all BSs in the network, what surrounding BSs are within a probable "listening distance" from the involved MS. The positions may be known to the network, or the MSC/BSC (12) could request this information from the mobile positioning service node (10) after the serving cell has become determined. If directional antenna information (antenna directions of sector sites) is also stored by the network, then this information can be

used for selecting the "best" detector cell (possibly in conjunction with information provided by the neighbor cell lists).

Note that the serving BS will normally also participate in making TOA measurements on the serving channel. If for some reason this is not possible (e.g., due to limited processing capabilities), another detector channel can be allocated in the same or another cell at the serving BS's site.

At step 110, the network allocates a TOA measurement channel (detector channel) in each of the surrounding BSs found. If there are no channels available in one or more of the surrounding cells, then as an option, active MSs can be handed over to other cells to allow measurements to be made in the surrounding cells. This is especially important if less than three detectors are available, because at least three detectors (at different sites) are needed for triangulation. Note that two consecutive timeslots can be allocated for long distances between the MS and certain detectors (e.g., to compensate for longer propagation times).

As another possibility, for example, if there are no idle channels available for measurements in the surrounding BSs, then the network can temporarily suspend communications on (the uplink of) a channel (e.g., a channel serving a low priority MS). The connection will not be lost, but there will be a slight interruption in the user speech and/or data. Alternatively, a special temporary detector channel can be allocated in parallel with the existing channel.

The complete Channel Description (retrieved at step 106) is conveyed to the detectors' BSs together with the FN Offset from the serving cell. The uplink (reception) part of the described channel is then activated in the detector's BS on the indicated TN and ARFCN alternative hopping sequence and, possibly, on two consecutive timeslots (the FN Offset can be used to adjust the detector's timing). The TSC is loaded into the detector's correlator, which is now prepared to listen for bursts with the correct Training Sequence. Reception is started at the activated channel, and if hopping is activated (e.g., H=1), the ARFCN is given by the hopping parameters and the actual FN. Note that if a temporary listening channel has been allocated, then that channel is not activated until the beginning of the Perform TOA measurement step (114) below. As such, communications on the original channel continues up to this moment.

Notably, the problems described above are typically due to the use of a conventional transceiver for positioning MSs (i.e, equipment that is normally used for maintaining traffic between the MS and the network). Theoretically, a similar problem can exist if there are concurrent positioning tasks attempting to allocate to the same receiver. An alternative approach is to use a separate positioning receiver (not normally used for traffic). In that case, there is no longer a conflict between traffic and positioning applications that would have been attempting to allocate the same communication resources.

More importantly, a separate positioning receiver can be designed with better performance (e.g., higher sensitivity) than a receiver used for ordinary traffic. This approach typically implies higher costs, which may be problematic if imposed for all transceivers of a BS. The above-described '466 Application describes such a solution using a separate positioning receiver (ModRX). However, this special positioning receiver is integrated into the BS. Nevertheless, the '466 Application does not describe such a solution for the GSM or similar digital TDMA cellular systems.

At step 112, the network schedules the timing for the TOA measurements. As such, the network reads the actual Global Time. The Global Time should be known before the TOA measurements are performed. The Global Time can be made available at all BSs for this embodiment, because it is assumed that they are all time-synchronized (e.g., using the GPS-derived time reference). However, the Global Time can also be made available at a central location in the network (e.g., at a BSC's site). In any event, it is advantageous if the Global Time is represented by the timing used for the air interface (i.e., global FN for a cell with an FN Offset=0), which enables synchronization of the measurements with timeslots and logical channel multiplexing.

From an actual global FN value, a subsequent "measurement FN" is calculated with a margin that considers the time it takes to convey a measurement order to each detector involved. Next, a TOA Measurement Command is conveyed to the allocated detectors, which includes a measurement start time and measurement period. Alternatively, instead of conveying a separate measurement command, this order can be carried within the same message as the message that activates the detector channel (e.g., in accordance with step 110 above).

FIGURE 3 is a diagram that helps to better illustrate the exemplary TOA

measurement method described above with respect to FIGURE 2. Referring to FIGUREs 2 and 3, at step 114, after the detectors involved receive the TOA measurement order, they await the TOA measurement start time (FN). At the measurement start time, which coincides with a timeslot border, sampling of the incoming data begins with a rate which is at least equal to the symbol rate (e.g., 270 kbits/s in the GSM). However, over-sampling is preferred for higher accuracy. The sampling process continues for the complete measurement window, as defined by the number of allocated consecutive timeslots. At the end of the sampling period, the recorded measurement data is matched (correlated) with the training sequence. The results of this correlation provide the measured TOA of the received signals.

As mentioned earlier, if using a temporary channel, the communications on the original channel are suspended. The (temporary) detector channel is activated immediately prior to the start of the measurement process. Note that as an option, the communications on the downlink of the original channel can be continued.

The TOA of a received burst can be measured as the time difference between the central part of the training sequence and the sampling time T (corresponding to t1, t2 and t3 in FIGURE 3). In addition to the TOA measurement, the signal strength and quality of the burst can also be measured. An example of such a quality measure is the relative strength of the correlation peak. These additional measurement values can be helpful in calculating the MS's position, including the positioning accuracy.

For the serving cell, the burst is located within the timeslot corresponding to the allocated channel. In the GSM, the burst's location is regulated by the Timing Advance (i.e., if the burst slides towards an end of the timeslot, the MS is commanded to advance its transmission of the burst, and vice versa for an earlier burst). Consequently, only one timeslot is needed in the serving cell to obtain an accurate TOA measurement.

Normally, the distances to the separate detectors are different. Consequently, the burst will slide into a subsequent timeslot for detectors that are farther away from the MS than the serving BS, and into the preceding timeslot for the closer detectors. The first situation is more likely, because the serving BS is normally closest to the MS. However, exceptions can occur, such as for example, if the closest BS is overshadowed by a building.

The Training Sequence is located in the center of the burst, and the remaining part of the burst is not needed for TOA measurements. Consequently, a large part of the burst can slide out of the timeslot without creating a problem. Also, it is possible to allocate a subsequent timeslot for the measurement when the distance to the serving cell is much shorter than the distance to the other detectors.

At step 116, the measured TOAs are reported to the network, the TDOAs are calculated, and the MS's position is then determined. The measurement period requested can cover one or more bursts. If the measurement period covers a number of bursts, a new TOA measurement (e.g., including signal strength and quality measurements) can be made in every TDMA frame during the period, and each measurement is logged separately along with an identification tag (e.g., FN). Subsequent to the measurement period, the full set of measurements is reported to the MSC/BSC (12), which collects the measurement information from all of the detectors involved, and forwards the collected information to the positioning service node (10). The positioning service node calculates a set of TDOA values for each set of TOA measurements taken (i.e., measurements with the same identification tag). As such, data indicating false bursts may be discarded. The calculated TDOAs are then averaged, and the MS's position is calculated based on the known positions of the detectors' BSs and the average TDOA values. If a temporary channel is being used for positioning, communications can be resumed in the original channel at the end of the measurement period.

The present method can also be used for MS positioning while using logical channel multiplexing and discontinuous transmissions. For example, in the GSM, an air interface timeslot can be used for communications with a single MS's full rate traffic channel (TCH/F). In a different configuration, two half rate channels (TCH/H) share the same basic physical channel (sequence of timeslots). Timeslots configured with a Stand-alone Dedicated Control Channel (SDCCH) contain a plurality (4 or 8) of SDCCH subchannels. For example there are only 4 such subchannels when the SDCCH is multiplexed with the common Broadcast Control Channel (BCCH) or Common Control Channel (CCCH). If applicable, the subchannel can be identified in the Channel Description message. The problem that arises is how to ensure that the measurement is made only on the correct subchannel. Note that the Traffic Channels

(TCHs) and the SDCCHs are also associated with the Slow Associated Control Channel (SACCH), respectively, which can also be used for TOA measurements.

Additionally, the transmission in a GSM network on a specific timeslot can be discontinuous. For speech (on a TCH), a Discontinuous Transmission (DTX) mode can be used, which means that if a speaker is quiet, the corresponding transmitter is turned off most of the time. Also, data traffic (also on the TCH) is naturally intermittent, which creates a similar problem.

A solution to these problems is to synchronize the TOA measurements with the known multiplexing scheme used for the network's air interface. In the GSM, a specific SDCCH subchannel is allocated to a specific part of the multiplexing scheme; namely, four consecutive TDMA frames of the so-called 51-frame multiframe. Consequently, measurements are allowed only at the FNs representing this subchannel (including the associated individual SACCH).

Although the TCH transmission can be intermittent, there is associated information which is always sent at a lower rate. In the DTX mode, Silence Descriptor information (SID frames) is sent every 104-frame period at a specific "location". Also, the SACCH channel is transmitted periodically and can be used, for example, for reporting MS measurements. Consequently, it is always possible to find information with which to perform measurements in a GSM or similar system.

In conclusion, for this embodiment, when a measurement time and period are scheduled, the following information should be considered. There should be allowed FNs to measure on (e.g., belonging to the correct subchannel), and for discontinuous transmissions, TDMA frames that are always used for transmission (e.g., the SACCH block) should be identified. Note that for discontinuous transmissions, some TDMA frame positions may or may not contain bursts. If bursts are received at these positions, the TOA measurements can be performed there anyway, in order to help improve the overall measurement statistics.

A second embodiment of the present invention is now described. Essentially, for this exemplary embodiment, the method illustrated by FIGURE 2 is modified and used to determine an MS's position by listening to an ongoing connection, but in an asynchronous network. The network can thus be assumed to be not synchronized for this embodiment (i.e., the timing of the air interface can be different for all cells in the

network). However, each of these cells should be accurately time-synchronized (e.g., using a GPS receiver at each BS's site).

In this case, subsequent to receipt of a Positioning Request (from a user or network operator), the positioning service node (10) makes note of the serving cell and actual serving channel involved. The network (MSC/BSC for the GSM) then allocates a plurality of detectors in the surrounding BSs for use in performing the positioning procedure. Since (as assumed) the detectors' cells are asynchronous with respect to the serving cell, at least two detectors should be allocated. The TOA sampling process, which is synchronized with the air interface timing in the serving cell, is performed simultaneously in all detectors involved. From one to several Normal Bursts from the MS of interest can be used for the TOA measurements.

Specifically, for this second embodiment of the present invention (referring again to the flow chart shown in FIGURE 2), upon receipt of the Positioning Request at the MSC/BSC (12), the following steps can be performed. At step 102, if the MS (14) whose position is to be determined is in the idle mode, at step 104, a call is set up between the network and the MS by the MSC/BSC. At step 106, the MS's occasional cell location and description of the allocated channel is retrieved from local storage in the MSC/BSC. As such, the same step followed for the first embodiment described above is again followed here, but with the following exception. Since the network is not synchronized for this embodiment, it is not particularly useful to retrieve the FN Offset values. However, the sync position, T1, can be read (i.e., the actual global time at the start of a TDMA frame). Again, the global time is assumed to be available at each BS's site (e.g., using a GPS receiver for a time reference). As such, the sync position, T1, is thus sampled at the start of an arbitrary TDMA frame. In order to be able to attain synchronization with logical channel multiplexing involved, the actual FN at the sync position (T1) can also be retrieved and used.

At step 108, the network locates the surrounding BSs (similar to step 108 employed in the first embodiment). At step 110, the network allocates the TOA measurement channels to be used (as in the first embodiment), but with the following exception. For this embodiment, the FN Offset information is not conveyed to the detectors' BSs. Instead, the sync positions of each detector's BS are retrieved similar to the method used for the serving cell (step 106 above). For example, if T2 is the

sync position for a specific detector's BS, and T_{frame} is the periodic time for the TDMA frame, then the number of TDMA frames between sync positions T2 and T1 can be expressed as:

$$No.\ of\ TDMA\ frames = \frac{(T2-T1)}{T_{frame}}. \qquad (1)$$

If the integer part of the equation (1) is subtracted out, the remainder represents the phase difference between the two cells. Using this phase information and the known TN value from the Channel Description for the serving cell, the timeslot number(s) to allocate in a detector can be calculated. As such, if the timeslots of the detector and serving cell are nearly in-phase, then only one timeslot has to be allocated for the measurement. Otherwise, two timeslots have to be allocated to obtain the same performance as obtained for the synchronized network embodiment.

More specifically, FIGUREs 4A and 4B are related diagrams that illustrate how the TN can be calculated (step 110) for allocation in a detector's BS. For example, referring to FIGURE 4A, if the timeslots of the detector BS2 and serving BS1 have a phase difference as shown (and the phase difference is defined as δ_{12}, e.g., in msecs), then the TN can be calculated by:

$$\delta_{12} = MOD((T2-T1);T_{frame}). \qquad (2)$$

FIGURE 4B (e.g., in which several TDMA frames are expanded to show timeslots) also illustrates how to calculate the TN if the timeslots of the detector BS2 and serving BS1 have a phase difference. For example, assume that a measurement is made on an MS which is allocated to Timeslot Number 5 in the serving BS1 (shown as TN1). That timeslot lags TN1*T_{slot} behind the TDMA frame border, where T_{slot} is the duration of a timeslot (e.g., about 0.6 msec in the GSM). Then two consecutive timeslots can be allocated (starting with TN2) in the detector BS2, which has to start before or at the same time as TN1. This calculation is based on the time difference between TN1 and the start of a TDMA frame in the detector BS2, or t_{dif}. In accordance with FIGURE 4B, the difference can be expressed as:

$$t_{dif} = TN1 * T_{slot} - \delta_{12}. \tag{3}$$

As such, the number of timeslots between the start of TN1 and the start of a TDMA frame in the detector BS2 is the integer part of the expression, t_{dif}/T_{slot}, or INTEGER(t_{dif}/T_{slot}). However, a problem arises when $TN1*T_{slot}$ is smaller than δ_{12} when t_{dif} becomes a negative value. In that case, TN2 also becomes a negative value, which corresponds to a timeslot in the preceding TDMA frame. Consequently, the number "8" is added to the negative TN2 to provide the correct value for TN2. A general expression for TN2 is thus given by:

$$TN2 = MOD(INTEGER(\frac{t_{dif}}{T_{slot}});8). \tag{4}$$

However, Equation (4) can be better expressed as:

$$\begin{aligned} TN2 &= INTEGER(\frac{t_{dif}}{T_{slot}}), \qquad if\ t_{dif} \geq 0 \\ &= 8 + INTEGER(\frac{t_{dif}}{T_{slot}}), \quad if\ t_{dif} < 0. \end{aligned} \tag{5}$$

At step 112, the schedule time for TOA measurements is calculated. However, the global time has already been retrieved (step 106) as the sync position, T1. As such, the TOA measurement time can be calculated by:

$$T_{meas} = T1 + n * T_{frame} + TN * T_{slot}, \tag{6}$$

where T_{slot} is the duration of the timeslot. The FN can then be recalculated as:

$$FN = FN + n, \tag{7}$$

where FN is in the serving cell at T_{meas}, and the value of "n" is set high enough to

provide enough margin for the time that elapses from the sampling of T1 through the allocation and activation of detectors and ordering of the measurements to be made. The sampling time is aligned with the start of the serving channel's timeslot (TN). The Measurement Commands are conveyed to the detectors using a similar method as described for step 112 for the first embodiment. The calculated FN is also conveyed to the detectors.

At step 114, the method is the same as described above for step 114 for the first embodiment, but with the following exception. For example, referring to the exemplary frame timing diagram illustrated in FIGURE 5, it can be seen that although T_{meas} is aligned with the serving channel's timeslot, T_{meas} can fall anywhere within a detector's (BS2 or BS3) timeslot. However, at the bottom portion of FIGURE 5, a number of possible window locations are shown with two consecutive timeslots. The present method's use of two consecutive timeslots for TOA measurements in a detector (e.g., in BS2 or BS3) guarantees a measurement window, which corresponds to the unshaded zones shown in FIGURE 5.

At step 116, the same method is followed as step 116 in the first embodiment (reporting TOA measurements, and calculating TDOAs and the MS's position), but with the following exception. For this embodiment, the tagging of TOA measurements should be based on the FN associated with the serving cell. Alternatively, the global time of each sample can be used instead.

There are also problems with logical channel multiplexing and discontinuous transmissions for this second embodiment. The resolution of these problems is similar to the resolution described above for the first embodiment, but with the following exception. For this embodiment, the FN used in a detector has no fixed relationship with the FN of the serving cell. Instead, the channel multiplexing used on the timeslot(s) allocated for detection should be based on the FN delivered in the TOA Measurement Command. It is known that at T_{meas}, this FN is equal to the FN in the serving cell. Then, if the measurement period is longer than one burst, the FN should be incremented every TDMA frame, starting with the delivered value of FN.

In accordance with a third exemplary embodiment of the present invention, TDOA positioning of an MS can be performed using controlled transmissions of access bursts in a synchronous network. Essentially, as in the first embodiment, the

network is assumed to be synchronized (i.e., the air interface timing is common for all cells in the network). However, the cells can be offset in the FN counting. Notably, this method is similar to a small extent to the method described in the above-cited U.S. Patent Application Serial No. 08/977,470 filed November 24, 1997 (hereinafter, the "'470 Application"). A significant difference is that the method used in this third embodiment measures TOAs instead of access delays. An access delay is the time between the start of a timeslot and the time the access burst is received. As such, the access delays can be used to calculate absolute distances, instead of the relative distances calculated by using the prior TDOA methods. However, in a synchronous network, the common timeslot border is the same as the global measurement time, so the access delay may be interpreted as a form of TOA measurement. As such, a TDOA method can also be used for calculating an MS's position, which would improve the measurement accuracy because the downlink's and MS's parts of the access delay are insignificant when measuring the different arrival times.

For this exemplary embodiment, after receipt of the Positioning Request for an MS (14), the serving cell and actual serving channel are noted. Next, detectors to be involved are allocated in a number of surrounding BSs. The MS is then commanded (e.g., by a Handover command) to begin transmitting access bursts. Sampling of the TOA of the transmitted signals is performed simultaneously in all of the allocated detectors. From one to several of the transmitted access bursts can be used for the TOA measurements. Alternatively, a variation of this method is to configure a common detector channel in all cells. and order the MS (whose position is to be determined) to transmit access bursts on this common channel.

There are a number of additional advantages of this method compared with the methods described above for the first and second embodiments. For example, the Training Sequence for this method is longer for an access burst than for a Normal Burst (e.g., in the GSM, 41 bits as opposed to 26 bits), which implies much higher sensitivity for this method. Furthermore, no burst will arrive before the beginning of the timeslot, because the transmitted access bursts are not Time Advance regulated. Moreover, the access burst transmissions are controlled. Consequently, there are no problems with intermittent transmissions. Access bursts arriving from MS's other than the MS involved can be discriminated by use of a control parameter (e.g.,

Handover Reference). Consequently, there is no need to synchronize with logical channel multiplexing. On the other hand, for this embodiment, the position of an MS can be determined, but the ongoing communications between the MS and the serving cell/channel may be disturbed in the process.

Specifically, FIGURE 6 is a flow diagram that illustrates a method for determining the position of an MS using controlled transmission of access bursts in a synchronous network, in accordance with the third exemplary embodiment of the present invention. For steps 202 and 204, these steps are similar to steps 102 and 104 in the first embodiment shown in FIGURE 2. At this point, for the next step, there are two options available. One option is to make TOA measurements on a common detector channel which is kept active in all cells. For this option, steps 206-210 can be bypassed (dotted line). The second option is to allocate detectors in the surrounding cells, as performed in the first and second embodiments.

In that event, at step 206 (similar to step 106 in the first embodiment) the serving cell information is retrieved. If the actual channel used for communication with the MS involved is to be used for the transmission of access bursts for measuring TOAs, then the Channel Description information is also retrieved at this step. Otherwise, if this communication channel is not to be used for TOA measurements, then the Channel Description information is not retrieved. However, the TSC is not needed in this event. Step 208 is similar to step 108 employed for the first embodiment.

At step 210, the method is similar to step 110 performed for the first embodiment, but with the following exceptions. Since the TOA measurements in this third exemplary embodiment use a different type of burst than used for the first and second embodiments, the detectors' correlators have to be loaded with this information. As such, in the GSM, the access bursts have 41 predefined "synch sequence bits" that can be used for this purpose. At each BS involved, the reception and sampling of the incoming data is started immediately after activation of the measurement channel on the allocated TN in all TDMA frames (regardless of the FN). The Normal Bursts transmitted from the served MS or other MSs on the same TN can be heard but discarded by the correlator(s) involved. The access bursts are detected (step 214 below).

Step 212 is substantially different than step 112 in the first embodiment. For example, the '470 Application describes two methods for commanding an MS to transmit access bursts. One such method is to issue a Handover Command, and the second method is to issue a special, non-standard Positioning Command. FIGURE 7 is a diagram that illustrates how the Handover Command method in the '470 Application can be implemented for this embodiment. Referring to FIGURE 7, the Handover Command contains, for example, a Cell Description which is equal to the allocated TOA measurement channel, and a Handover Reference. An asynchronous handover procedure is indicated, which commands the MS to transmit access bursts continuously until a time-out period has elapsed. After the time-out period, the MS reverts to the original channel used. A special case (preferred) is to perform a handover to the MS's own cell and channel, which minimizes the risk of losing the MS's connection.

In using this handover method, the new channel is synchronized with the original channel. Consequently, a synchronous handover procedure can be used instead. In this case, the MS can transmit access bursts in only four consecutive TDMA frames, and then it switches to transmitting Normal Bursts. With this method, it is possible to command a handover to an original channel in the serving cell, which implies a shorter interruption of the ongoing connection than for an asynchronous handover procedure. Note, however, that four access bursts may not be sufficient to attain the accuracy required.

At step 214, the same method followed in step 114 of the first embodiment can be used, but with the following exceptions. The measurement process was already begun in step 210. At step 214, the access bursts transmitted at step 212 are detected. FIGURE 8 illustrates the situation when the access burst transmitted by a MS (as a result of step 210) is received by the serving BS and the detectors. The TOA values (t1, t2, t3) are measured with respect to the timeslot border. Using this method, the access burst cannot arrive prior to the beginning of the timeslot (since the network is synchronized). In the serving BS, the TOA value, t1, corresponds to the access delay, which can be used to command the MS to advance its timing when Normal Bursts are being transmitted.

Step 216 is similar to step 116 in the first embodiment, but with the following

exception. The measurement period is not related to any fixed point in time. Instead, the detectors can be directed to measure the TOA of a number of consecutive access bursts from the MS involved, or during a certain period of time, start measuring with the first detected and accepted access burst. The acceptance of an access burst can be based on the Handover Reference or a similar reference. Advantageously, there are no problems related to logical channel multiplexing or discontinuous transmissions when the present method of controlled transmission of access bursts is used.

In accordance with a fourth exemplary embodiment of the present invention, TDOA positioning of an MS can be performed using controlled transmissions of access bursts in an asynchronous network. Essentially, this method is a variant of the method described above for the third embodiment, except this method is for asynchronous networks. Referring to FIGURE 6 (which can also be used to illustrate the fourth embodiment), upon receiving a Positioning Request at the MSC/BSC, the following steps can be performed.

At steps 202 and 204, similar to the steps described above for the third embodiment, if the MS involved is in the idle mode, than a connection is setup with the MS and the network. Step 206 is similar to step 206 in the third embodiment, but with the following exception. If the network is not synchronized, then it is not useful to retrieve an FN Offset. However, the "sync position" T1 can be read (i.e., the actual global time at the start of a TDMA frame). The global time is assumed to be available at each site (e.g., using GPS receivers). The sync position, T1, is thus sampled at the start of an arbitrary TDMA frame. In order to be able to synchronize the network with logical channel multiplexing, the actual FN at the sync position can also be retrieved.

Step 208 is similar to step 208 for the third embodiment (the surrounding BSs are located). Step 210 is similar to step 210 for the third embodiment, but with the following exception. The reception and sampling of incoming data are not started immediately at activation. Instead, the method used for step 110 in the second embodiment is used (i.e., the start time of the TOA measurements is scheduled). For example, step 110 in the second embodiment describes how the sync position of each detector's BS in the asynchronous network is calculated. The same description can be used at step 210 herein for the fourth embodiment.

At step 212, the MS involved is commanded to transmit access bursts on the

measurement channel. The method used for step 112 in the second embodiment (calculating the measurement time, T_{meas}) is used for step 212 in the fourth embodiment. When calculating the global sampling time, an additional margin should be calculated for the time it takes to command the transmission of access bursts. Next, the step 212 for the third embodiment is performed.

At step 214, the method described above for step 114 in the second embodiment is used to perform the TOA measurements. FIGURE 9 is a diagram that illustrates how the TOA measurements can be made, in accordance with the fourth exemplary embodiment of the present invention. The description provided above for step 114 in the second embodiment can also be used herein with respect to FIGURE 9. As a result of using two-slot measurement windows in the detectors' BSs for this step, a guaranteed measurement window can be provided (unshaded portion) for each detector. Finally, for step 216, the measured TOAs are reported, and the TDOAs and the MS's position are calculated. This step is similar to step 116 described above for the second embodiment. As such, in accordance with fourth embodiment, there are no problems associated with logical channel multiplexing and discontinuous transmissions when the present method with controlled transmission of access bursts is used.

Although a preferred embodiment of the method and apparatus of the present invention has been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

WHAT IS CLAIMED IS:

1. A method for use in determining the position of a mobile terminal in a mobile communications network, comprising the steps of:

retrieving an identity of a serving cell and serving channel allocated for said mobile terminal;

locating a plurality of base stations surrounding said serving cell;

allocating a measurement channel for each of said located plurality of base stations;

scheduling a measurement time for said located plurality of base stations; and

performing a time of arrival measurement in each of said located plurality of base stations.

2. The method of Claim 1, further comprising the steps of:

calculating a time difference of arrival value based on each of said time of arrival measurements; and

determining said position of said mobile terminal based on said time difference of arrival values and a known location for each of said located plurality of base stations.

3. The method of Claim 1, wherein said network comprises a TDMA digital cellular network.

4. The method of Claim 1, wherein said network comprises a GSM network.

5. The method of Claim 1, wherein said network comprises a synchronous network.

6. The method of Claim 1, wherein said network comprises an asynchronous network.

7. A method for use in determining the position of a mobile terminal in

a mobile communications network, comprising the steps of:

retrieving an identity of a serving cell and serving channel allocated for said mobile terminal;

locating a plurality of base stations surrounding said serving cell;

allocating a measurement channel for each of said located plurality of base stations;

ordering said mobile terminal to transmit at least one access burst on said measurement channel; and

performing a time of arrival measurement in each of said located plurality of base stations.

8. The method of Claim 7, further comprising the steps of:

calculating a time difference of arrival value based on each of said time of arrival measurements; and

determining said position of said mobile terminal based on said time difference of arrival values and a known location for each of said located plurality of base stations.

9. The method of Claim 7, wherein said network comprises a TDMA digital cellular network.

10. The method of Claim 7, wherein said network comprises a GSM network.

11. The method of Claim 7, wherein said network comprises a synchronous network.

12. The method of Claim 7, wherein said network comprises an asynchronous network.

13. A system for use in determining the position of a mobile terminal in a mobile communications network, comprising:

a serving cell and serving channel allocated for said mobile terminal; and

a plurality of base stations surrounding said serving cell, each of said plurality of base stations including a measurement channel, and means for scheduling a measurement time and performing a time of arrival measurement.

14. The system of Claim 13, further comprising:

said network further including means for calculating a time difference of arrival value based on each of said time of arrival measurements and determining said position of said mobile terminal based on said time difference of arrival values and a known location for each of said plurality of base stations.

15. The system of Claim 13, wherein said network comprises a TDMA digital cellular network.

16. The system of Claim 13, wherein said network comprises a GSM network.

17. The system of Claim 13, wherein said network comprises a synchronous network.

18. The system of Claim 13, wherein said network comprises an asynchronous network.

19. A system for use in determining the position of a mobile terminal in a mobile communications network, comprising:

a serving cell and serving channel allocated for said mobile terminal;

a plurality of base stations surrounding said serving cell, each of said plurality of base stations including a measurement channel; and

means for ordering said mobile terminal to transmit at least one access burst on said measurement channel, and performing a time of arrival measurement in each of said plurality of base stations.

20. The system of Claim 19, further comprising:

said network further including means for calculating a time difference of arrival value based on each of said time of arrival measurements and determining said position of said mobile terminal based on said time difference of arrival values and a known location for each of said plurality of base stations.

21. The system of Claim 19, wherein said network comprises a TDMA digital cellular network.

22. The system of Claim 19, wherein said network comprises a GSM network.

23. The system of Claim 19, wherein said network comprises a synchronous network.

24. The system of Claim 19, wherein said network comprises an asynchronous network.

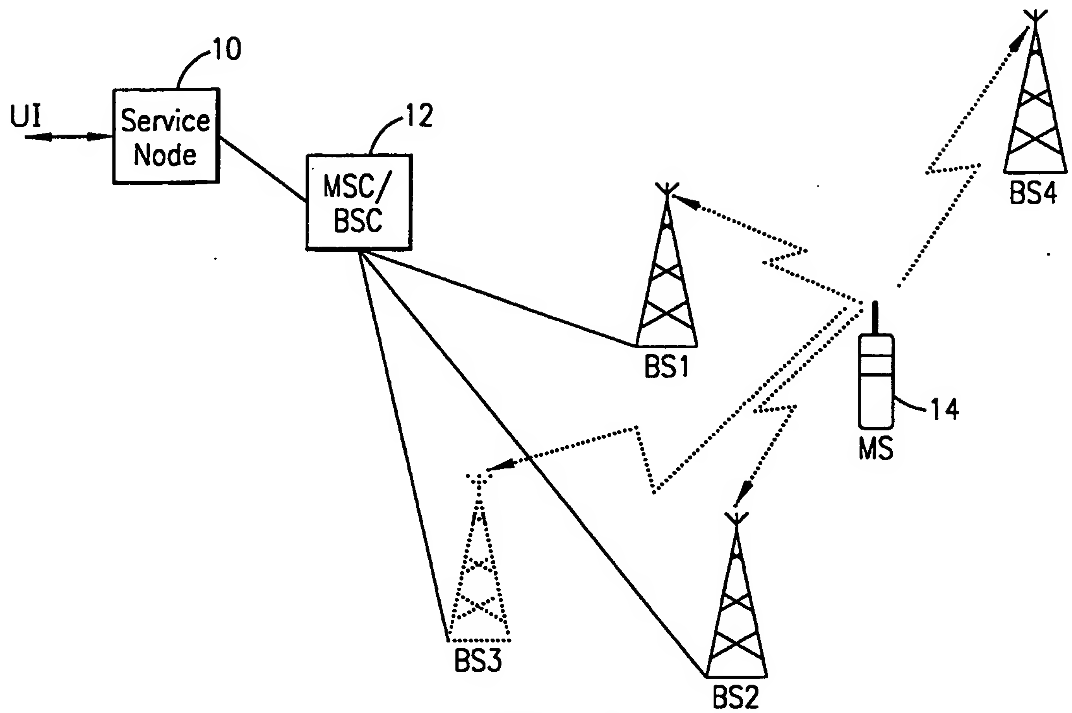

10
UI
Service Node
12
MSC/ BSC
BS1
BS2
BS3
BS4
14
MS

FIG. 1

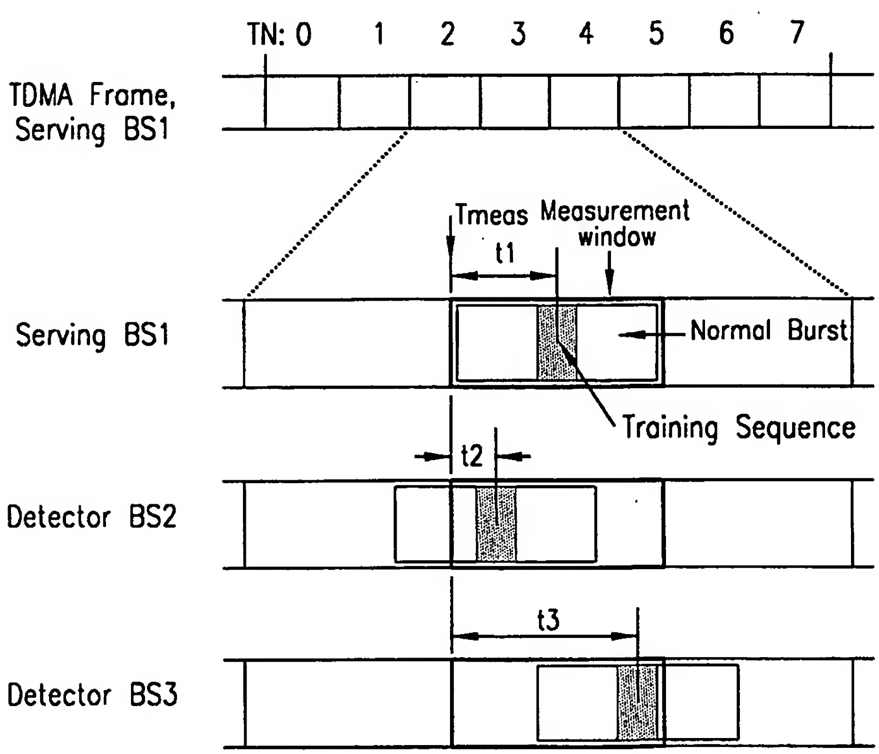

TN: 0 1 2 3 4 5 6 7
TDMA Frame, Serving BS1
Tmeas
Measurement window
t1
Serving BS1
Normal Burst
Training Sequence
t2
Detector BS2
t3
Detector BS3

FIG. 3

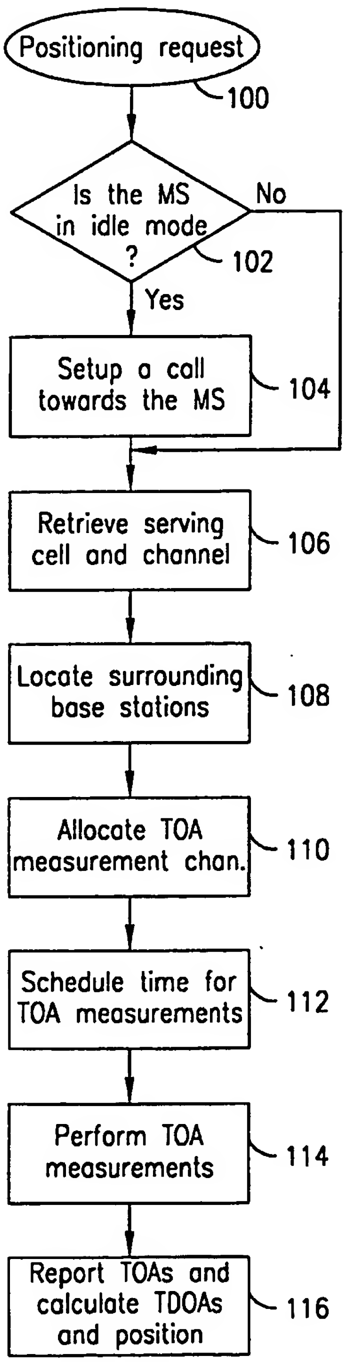

Positioning request
100
Is the MS in idle mode ?
102
No
Yes
Setup a call towards the MS
104
Retrieve serving cell and channel
106
Locate surrounding base stations
108
Allocate TOA measurement chan.
110
Schedule time for TOA measurements
112
Perform TOA measurements
114
Report TOAs and calculate TDOAs and position
116

FIG. 2

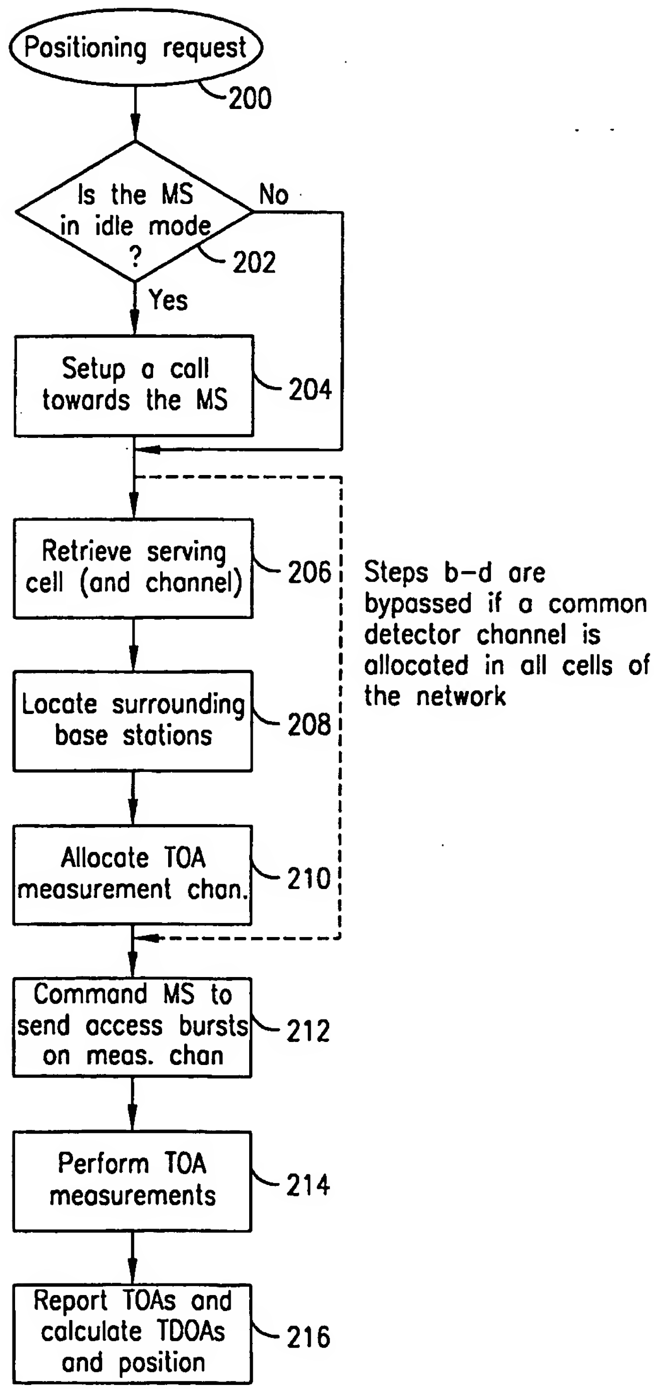

Positioning request
200
Is the MS in idle mode ?
202
No
Yes
Setup a call towards the MS
204
Retrieve serving cell (and channel)
206
Locate surrounding base stations
208
Allocate TOA measurement chan.
210
Steps b–d are bypassed if a common detector channel is allocated in all cells of the network
Command MS to send access bursts on meas. chan
212
Perform TOA measurements
214
Report TOAs and calculate TDOAs and position
216

FIG. 6

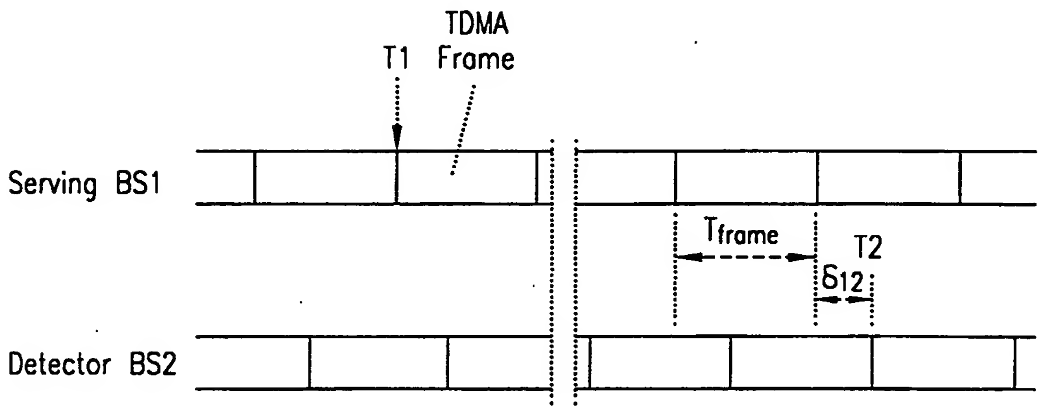

TDMA
Frame
T1
Serving BS1
Tframe
T2
δ12
Detector BS2

FIG. 4A

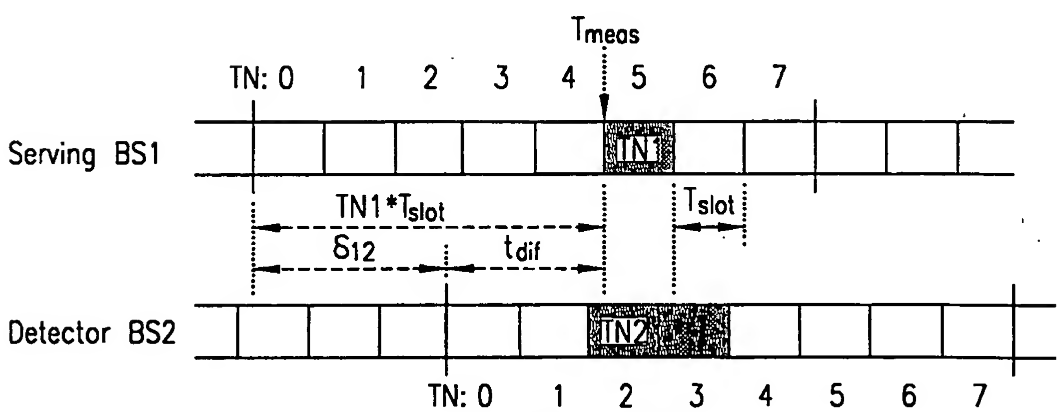
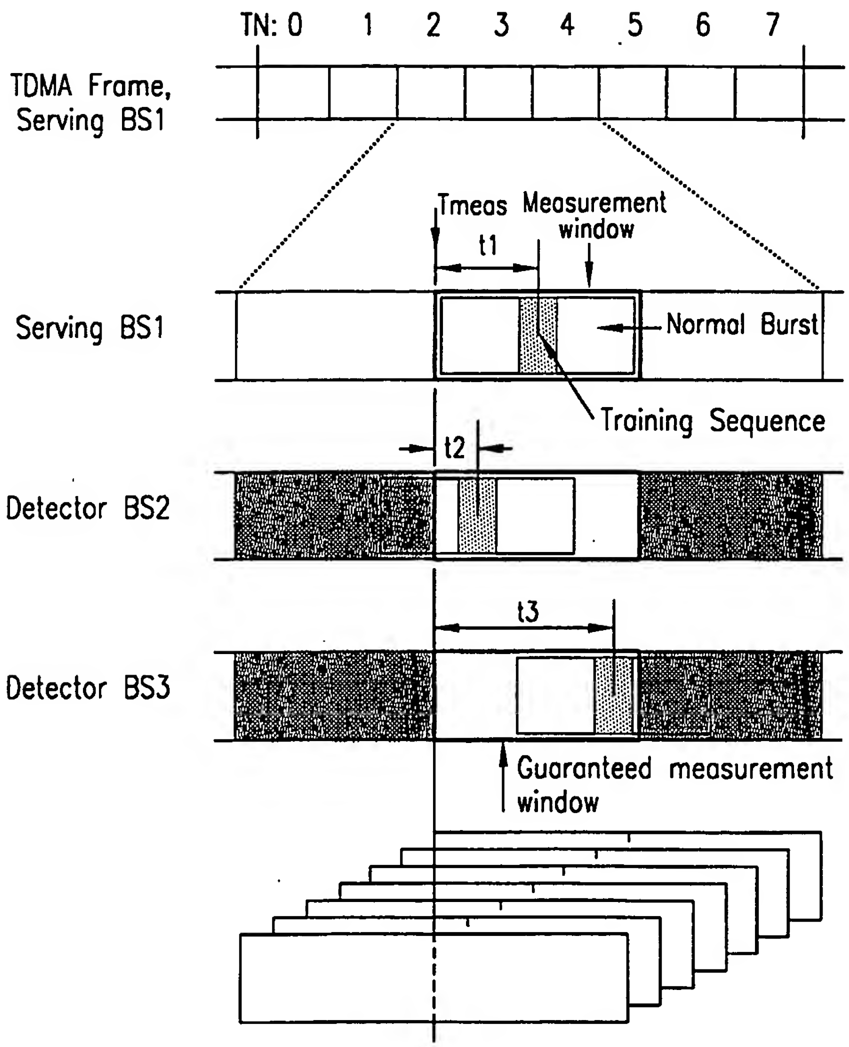

Tmeas
TN: 0 1 2 3 4 5 6 7
Serving BS1
TN1
TN1*Tslot
Tslot
δ12
tdif
Detector BS2
TN2
TN: 0 1 2 3 4 5 6 7

FIG. 4B



Some possible locations of 2-slot measurement windows in detector BS

FIG. 5

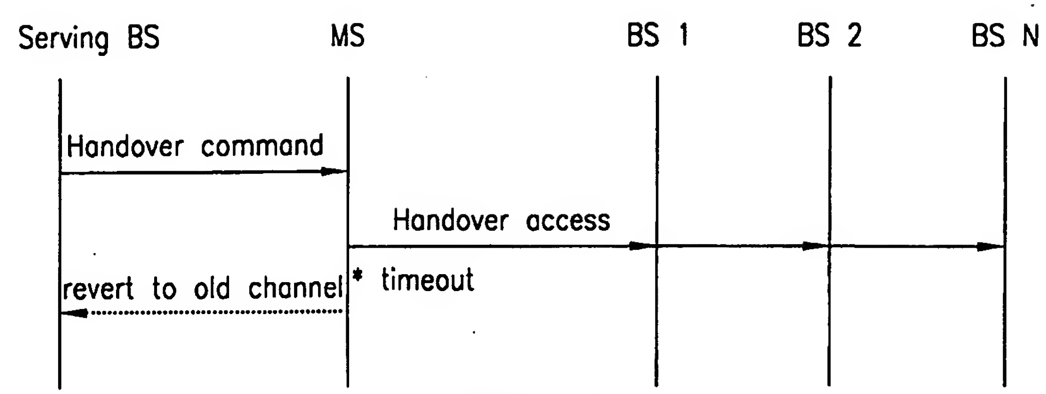

Serving BS
MS
BS 1
BS 2
BS N
Handover command
Handover access
revert to old channel
* timeout

FIG. 7

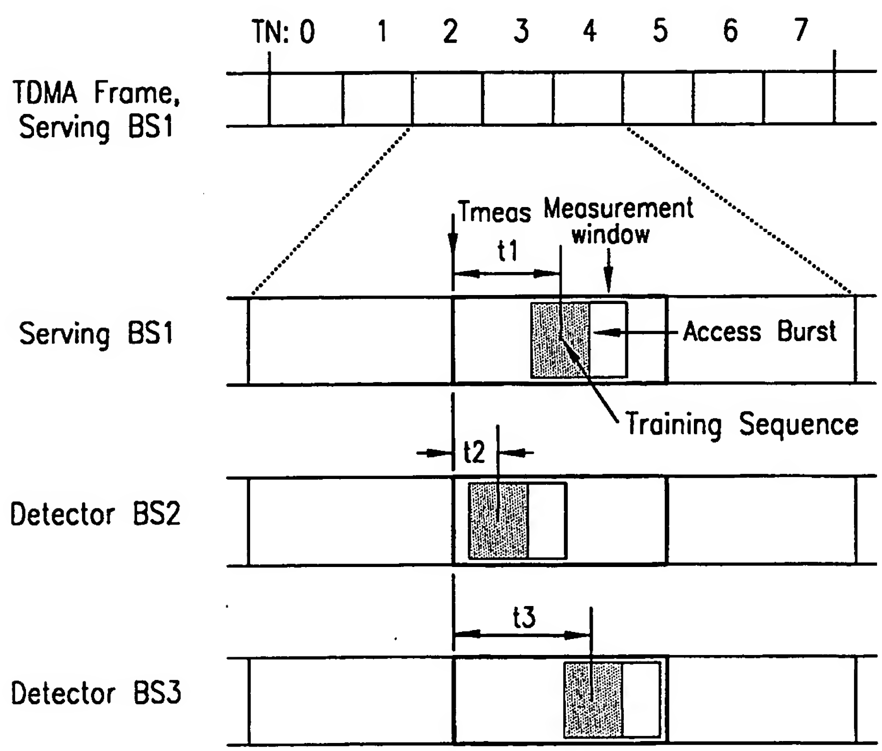
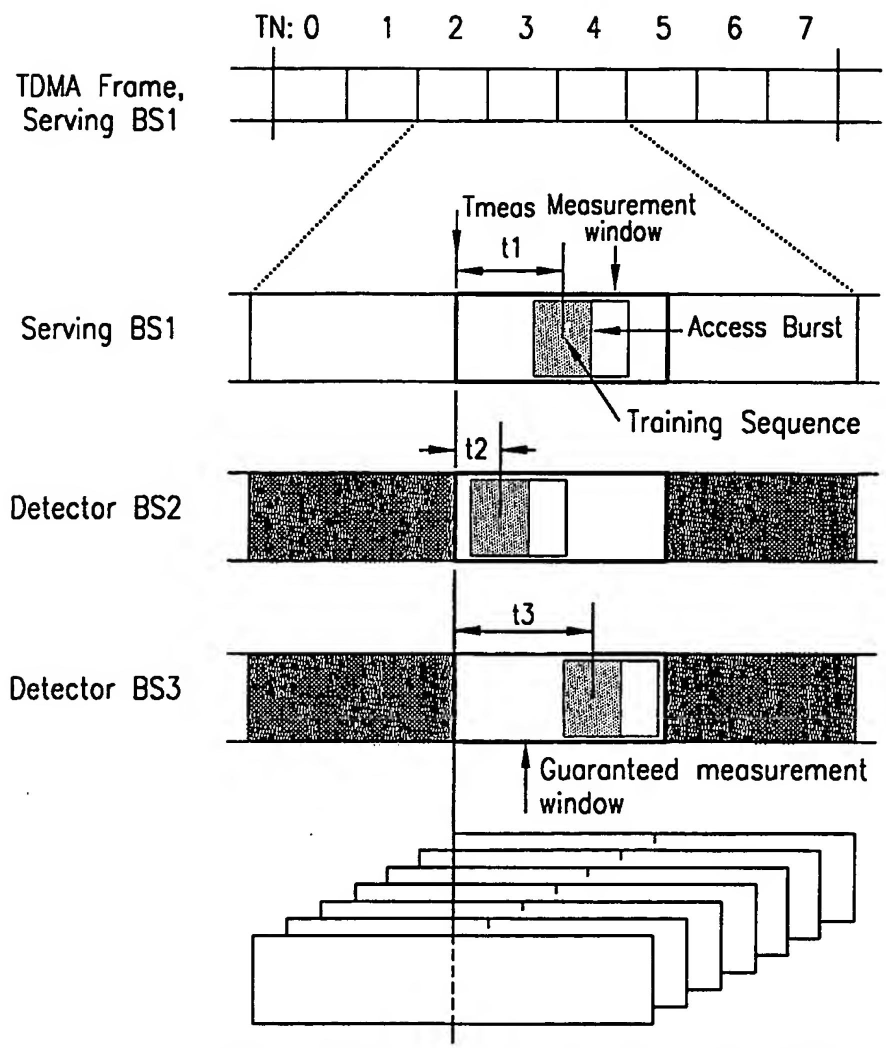

TN: 0
1
2
3
4
5
6
7
TDMA Frame, Serving BS1
Tmeas
Measurement window
t1
Serving BS1
Access Burst
Training Sequence
t2
Detector BS2
t3
Detector BS3

FIG. 8



Some possible locations of 2–slot measurement windows in detector BS

FIG. 9

INTERNATIONAL SEARCH REPORT

Inte .onal Application No
PCT/SE 98/02198

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/22 H04Q7/38 G01S5/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 27711 A (NOKIA TELECOMMUNICATIONS OY ;PASKI PERTTI (FI); SUONVIERI JUKKA (F) 31 July 1997	1,3,4,6, 7,9,10, 12,13, 15,16, 18,19, 21,22,24
Y	see page 3, line 11 - line 21 see page 5, line 5 - line 20 see page 7, line 20 - page 9, line 28 see page 10, line 28 - page 11, line 20 ---	2,8,14, 20

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 March 1999	30/03/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gerling, J.C.J.

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/SE 98/02198

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 608 410 A (STILP LOUIS A ET AL) 4 March 1997 see column 2, line 41 - column 3, line 7 see column 6, line 38 - line 54 see column 7, line 5 - line 17 see column 7, line 35 - line 40 see claim 1 ---	2,8,14, 20
A	WO 97 30360 A (ERICSSON TELEFON AB L M) 21 August 1997 see page 3, line 5 - page 6, line 5 see page 7, line 6 - line 11 see page 10, line 3 - page 11, line 25 see page 12, line 23 - page 14, line 31 see page 18, line 10 - page 21, line 23 ---	1,7,13, 19
A	EP 0 767 594 A (NOKIA MOBILE PHONES LTD) 9 April 1997 see column 3, line 25 - line 41 see column 4, line 29 - line 59 see column 6, line 3 - line 36 see column 9, line 15 - line 22 ---	1,2,7,8, 13,14, 19,20
A	WO 96 35306 A (TELECOM SEC CELLULAR RADIO LTD ;MUNDAY PETER ROBERT (GB); GOETZ IA) 7 November 1996 see page 2, line 30 - page 3, line 7 see page 4, line 6 - line 22 see page 6, line 11 - page 7, line 30 see page 9, line 26 - page 13, line 5 ---	1,2,7,8, 13,14, 19,20
A	DE 44 09 178 A (SIEMENS AG) 21 September 1995 -----	

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte .onal Application No
PCT/SE 98/02198

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9727711	A	31-07-1997	FI	960381	A	27-07-1997
			AU	1547597	A	20-08-1997
US 5608410	A	04-03-1997	US	5327144	A	05-07-1994
			AU	6820694	A	12-12-1994
			WO	9427161	A	24-11-1994
			AT	165169	T	15-05-1998
			AU	677292	B	17-04-1997
			AU	6094094	A	12-12-1994
			BR	9406463	A	30-01-1996
			CA	2161333	A,C	24-11-1994
			DE	69409645	D	20-05-1998
			DE	69409645	T	06-08-1998
			EP	0700525	A	13-03-1996
			JP	2843951	B	06-01-1999
			JP	8508381	T	03-09-1996
			SG	48730	A	18-05-1998
			WO	9427160	A	24-11-1994
			ZA	9401019	A	25-08-1994
WO 9730360	A	21-08-1997	AU	1817497	A	02-09-1997
			CA	2245878	A	21-08-1997
			EP	0883968	A	16-12-1998
			SE	9600577	A	17-08-1997
EP 0767594	A	09-04-1997	FI	954705	A	04-04-1997
WO 9635306	A	07-11-1996	AU	701275	B	21-01-1999
			AU	5507296	A	21-11-1996
			CA	2219783	A	07-11-1996
			EP	0824840	A	25-02-1998
			NO	975041	A	30-12-1997
DE 4409178	A	21-09-1995	NONE			

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